NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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SUBJECTIVE PREFERENCES AND DETECTION RANGES IN SONAR CONTROL ROOMS UNDER RED AND BLUE LIGHT

by

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Naval Medical Research and Development Command
Research Work Unit M0100-PN.001-1014

Released by:

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Commanding Officer
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SUMMARY PAGE

PROBLEM

To measure the effects of red and blue ambient illumination on comfort and performance in sonar trainers.

FINDINGS

Most sonar technicians preferred blue to red illumination although there were sizeable differences among the crews of different submarines. There were no differences in detection ranges measured in red or blue illumination.

APPLICATIONS

These data will assist in specifying the optimum conditions for viewing visual displays in sonar control rooms and in other control areas where CRTs are used to display information.

ADMINISTRATIVE INFORMATION

This research was conducted under Naval Medical Research and Development Command Work Unit M0100-PN.001-1014 - "Optimum conditions for watch in sonar shacks." It was submitted for review on 27 Aug 1982, approved for release on 22 Sep 1982, and designated as NSMRL Rep. No. No. 991.

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ABSTRACT

This report summarizes the results of two studies conducted in sonar trainers at Naval Submarine School comparing red and blue ambient illumination in sonar control rooms. In one, a subjective assessment of blue, white, and red was made in the SSBN Sonar Operational Trainer; in the other, detection ranges were measured on the 21B64A/AN/BQQ-5A trainer under red and blue light. The sonar crews of two submarines voiced strong preferences for blue light while those of a third preferred red. Detection ranges did not change with the color of the illumination.

Low level red lighting has traditionally been employed in all submarine control areas, including the sonar control room. The original reason was of course to promote dark adaptation for the men in the old fleet-type submarines that regularly surfaced at night. When this need was eliminated, red lighting was retained primarily for the periscope operator and also in case of an unanticipated need to surface.

The continuing requirement for red lighting in submarines is controversial,[1] however, and particularly difficult to justify in sonar control rooms. When sonar information was only auditory, the type of lighting was unimportant, but today the information is displayed visually as well. In fact in the newest systems, the information from sonar sensors is almost entirely displayed upon consoles employing cathode-ray tubes (CRTs).

Dissatisfaction with the existing system, apparently, led one submarine to try out broadband blue lighting on its own. The manual on Lighting on Naval Ships contains a chapter "Blue Illumination for Radar Systems Display Consoles."[2] The rationale for this lighting is a division of the visible spectrum into halves: the short wavelength (blue) is used for general room illumination while the long wavelength (yellow) is used for the CRT. In the early trials of this procedure,[3,4] the division was achieved by placing a yellow filter over the radar screen; this filter effected the split of the spectrum both by limiting the output of the radar to long wavelengths and by not transmitting any of the blue ambient illumination to the radar phosphor.

The initial trial of blue lighting was popular and prompted an official test installation on the USS GROTON[5]. Word spread through the submarines in the local area, and since blue filters are available in GSA catalogues, many submarines changed over.

At the same time, as part of a research project to determine the optimum conditions for watch in sonar control rooms, the staff of NSMRL were surveying lighting conditions aboard local submarines. At the time of our survey 4 out of 12 submarines had switched to blue lighting and many men reported liking it. In addition there were many complaints voiced about red lighting.

Our analysis of the popularity of blue over red suggested four possible reasons.[6] First is the well-known psychological effect of improved morale which stems from any change that the participants perceive as being done for their benefit.[7] Second, it is a fact of physiological optics that long wavelengths (red light) focus farther behind the retina than light of shorter wavelengths and thus require more accommodation to see clearly at the same distance. This can be particularly uncomfortable for hyperopes (far-sighted individuals) or for older men who are utilizing most of their accommodative power under close viewing conditions and do not have the reserve for the long wavelengths. Third, blue lights, as installed in the sonar control rooms, provide much more total light than do the red. Even if they measured the same with a photopic light meter (which they did not, blue was generally brighter), blue is much more effective in providing light at the low levels found in the sonar control room than is red. Finally, it is possible that there is a real enhancement of visual sensitivity inherent in the use of blue lighting.

Some of the possible reasons for the shift to blue suggests a real advantage to its use, while others are relatively trivial. In order to ascertain which one or ones were real, a series of experiments was initiated both in the laboratory and in sonar operational trainers (SOT) at the Naval Submarine School.

This report summarizes the results of two studies at NAVSUBSCOL. In one, a subjective assessment of blue, white, and red lighting was made in the sonar trainer; in the second, detection ranges were measured on the 21B64A/AN/BQQ-5A trainer under red and blue light.

EXPERIMENT I

This experiment was designed to measure the subjective responses of sonar technicians to the color of the ambient illumination in the sonar control room. The SOT was chosen for this evaluation since it duplicates the sonar control rooms on many fleet ballistic missile (FBM) type submarines. Three colors of ambient illumination (red, white, and blue) were used for this assessment.

Method

The SOT is normally red-lighted; the color is obtained by placing red plastic sleeves over the fluorescent light bulbs. For blue, these were replaced by similar sleeves obtained from the GSA catalogue. The amount of light transmitted by the red and blue filters are very similar, two to four percent of the total light. The exact value depends of course on the type of fluorescent light with which the sleeve is used. For Cool White fluorescents, the value is about 2% for both the red and blue; for Daylight fluorescent the blue transmits slightly more light, about 4%.

Neutral or colorless sleeves are not available in GSA catalogues. Thus to obtain the comparable low levels of white illumination, filters were constructed of black cloth and hung just below the face of the fluorescent fixtures.

Measures of the illumination falling on various pieces of equipment were made throughout the sonar control room, with the red, blue, and black filters in place. The levels varied from .05 to .15 foot-candles (fc) depending upon the position of the sonar suite with respect to the light fixtures. The values for red, white, and blue, however, were always the same on any piece of equipment. Thus, for example, the illumination falling on the waterfall display of the AN/BQR-21 was .1 fc, regardless of whether it was red, white, or blue. On the screen of the AN/BQR-7E, it was .05 fc for all three colors.

Sonar crews undergoing responsive training were used in this evaluation. These crews normally spend three days or more working together in the trainer, operating all of the equipment. The color of the lights in the SOT was changed every day for the first three days as the men underwent their normal training procedure. Crews from three submarines were employed, and the order of the colors was counterbalanced so that each color appeared first, second, and last for one of the crews.

At the end of each day, the men were asked to fill out a mood scale and to answer three questions about the lights. The questions were: "Do you think the color of the general illumination (1) helps or hinders detection of low signal to noise ratio targets? (2) is relaxing or fatiguing? (3) is easy or difficult to work in?

The Mood Scale is shown in the Appendix. It was developed by Laverne Johnson and Paul Naitoh[8] at the Naval Health Research Center and has been used extensively in their research on fatigue. It is described as a short, self report questionnaire by which the individual describes his feelings of alertness, emotional state, social disposition and general mood.

In addition, following the third day of operating in the SOT, the men were asked to compare their impressions of the three colors of ambient illumination by answering the following questions: (1) Which of the three colors of general illumination (red, blue, or white) was easiest to work in? (2) Do you believe any of them made low S/N targets easier to detect? (3) Do you have complaints about any of them. We also asked for any comments they wished to make.

Results

The tabulation of results of the first two questions comparing the colors of ambient illumination are given in Table I. There was a general preference for blue lighting: for example, 28 out of 41 men said blue was the easiest of the three colors to work in and nearly half of the sonar technicians said blue made low signal/noise targets easier to detect.

Despite the overall preponderence of preference for blue illumination, a distinct difference among submarines is also apparent in Table I: men on the first two submarines almost unanimously preferred blue, while the men from the third unanimously disliked blue. The current lighting on all three submarines is red so this factor does not explain the differences.

The question concerning complaints elicited a number of common responses, particularly that the lights caused glare on the displays, were tiring, and gave eye strain or resulted in headaches. The color to which the complaint was registered depended however upon the submarine. For example, on submarine 2, out of eight complaints registered, six were of glare or difficulty seeing with red light and the other two were that the white light was gloomy. On boat 3, on the other hand, nine out of ten complaints were of glare or eye strain with the blue illumination.

Table II summarizes how each of the colored lights was described at the end of the day after training in the SOT in that particular color. Thus on submarine 1,24% of the men reported that red illumination had helped them detect difficult targets; the percentage was the same for white, but after the day's training in blue light, 81% reported the light helped. The percentages were similar for submarine 2 and again reversed for submarine 3.

The strong preferences for a specific color are highly significant. The data in Table I, for example, can be compared with the number of men

Table I. Number of men responding to questions comparing the colors of ambient illumination

Submarine	N	Blue	White	Red	No difference
		Which of three colors easiest to work in?			
1	22	19	2	0	1
2	9	9	0	0	0
3	10	0	1	9	0
	41	28	3	9	1
		Which of the colors, if any, made low S/N targets easier to detect?			
1	22	15	0	1	6
2	9	4	0	0	5
3	10	0	0.5	3.5	6
	41	19	0.5	4.5	17

Table II. Description of lights by men at end of day's work (Data are % of men)

Submarine	The Color of Illumination is described as:		
	Helping detection of low S/N targets	Relaxing	Easy to work in
Submarine 1			
Red	24	10	19
White	24	24	29
Blue	81	95	90
Submarine 2			
Red	40	30	30
White	30	30	20
Blue	90	90	90
Submarine 3			
Red	50	40	60
White	20	30	50
Blue	10	40	30

expected by chance if one-third of the men on each boat preferred each color. Chi-Square values are significantly different from the chance expectation, at a probability less than .01, for each of the three submarines, although of course in different directions.

Predictably, the results of the mood questionnaire were in agreement with the answers to the general questions. Thus, the majority of the men reported feeling good (active, alert, cheerful, efficient, etc.) in blue light; at the same time that they reported less negative feelings (annoyed, defiant, drowsy, dull, etc.). Similarly, there were large differences in the results of the mood scale among submarines. The average P (positive) and N (negative) scores are given in Tables III and IV by submarine: Subs 1 and 2 had higher P and lower N scores for blue lighting while for sub 3, the reverse held.

The differences in mood scales obtained under the various colors of illumination are statistically significant. If one considers only individuals, without regard to the submarine to which they were attached, analysis of variance shows significantly better moods reported under blue illumination. If one considers the submarine, this holds for only two of the three.

EXPERIMENT II

This experiment was designed to determine whether the color of the illumination had a measurable effect on the detection of low signal-to-noise ratio targets. The 21B64A/AN/BQQ-5A trainer at NAVSUBSCOL was chosen for the measures since it is possible to set up realistic problems on it, have sonar technicians operate the system to search for contacts, and obtain a measure of the distance at which the contact is detected.

Method

Each problem was set up with the contact originally out of range and approaching at a constant speed on a specific bearing. The operator viewed the passive broadband displays and attempted to locate the contact as quickly as possible. He was instructed to operate the AN/BQQ-5A system to the best of his ability, to use as many options as he desired, to change display configurations, and to call for own ship's maneuvers as he saw fit.

Since detection ranges are influenced by many variables unrelated to lighting,[9] a number of conditions were kept constant for each run. These included the speed of both own ship and contact, the depth, location, sea state, and shipping density.

Sleeves formed of red or blue plastic filters were placed over the fluorescent fixtures in the training room and the rheostat adjusted to provide the desired quantities of light. The red and blue sleeves were obtained from the GSA catalogue and measured with a Cary spectrophotometer. The spectral transmission curves of the filters are shown in Fig. 1.

Illumination falling on the display consoles was kept constant at .25 fc; this level is near the upper limit of values found on the AN/BQQ-5A displays of local submarines.[6] The illumination was measured with a Gossen meter, equipped to measure normal, photopic levels of illumi-

Table III. The average ($\bar{X}$) and standard deviation (σ) of men on the positive item of the Mood Scale

Submarine	N	Red		White		Blue	
		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
1	21	22.0	±11.1	25.5	±13.2	31.1	±6.8
2	10	23.0	±11.1	20.8	±10.0	28.7	±6.5
3	10	27.1	± 9.7	25.5	± 9.7	21.5	±5.9

Table IV. The average ($\bar{X}$) and standard deviation (σ) of men on the negative items of the Mood Scale

Submarine	N	Red		White		Blue	
		$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
1	21	8.7	±4.9	6.9	±6.8	2.9	±3.1
2	10	9.7	±5.8	10.9	±8.2	5.8	±6.3
3	10	5.2	±6.1	7.9	±4.9	8.7	±6.9

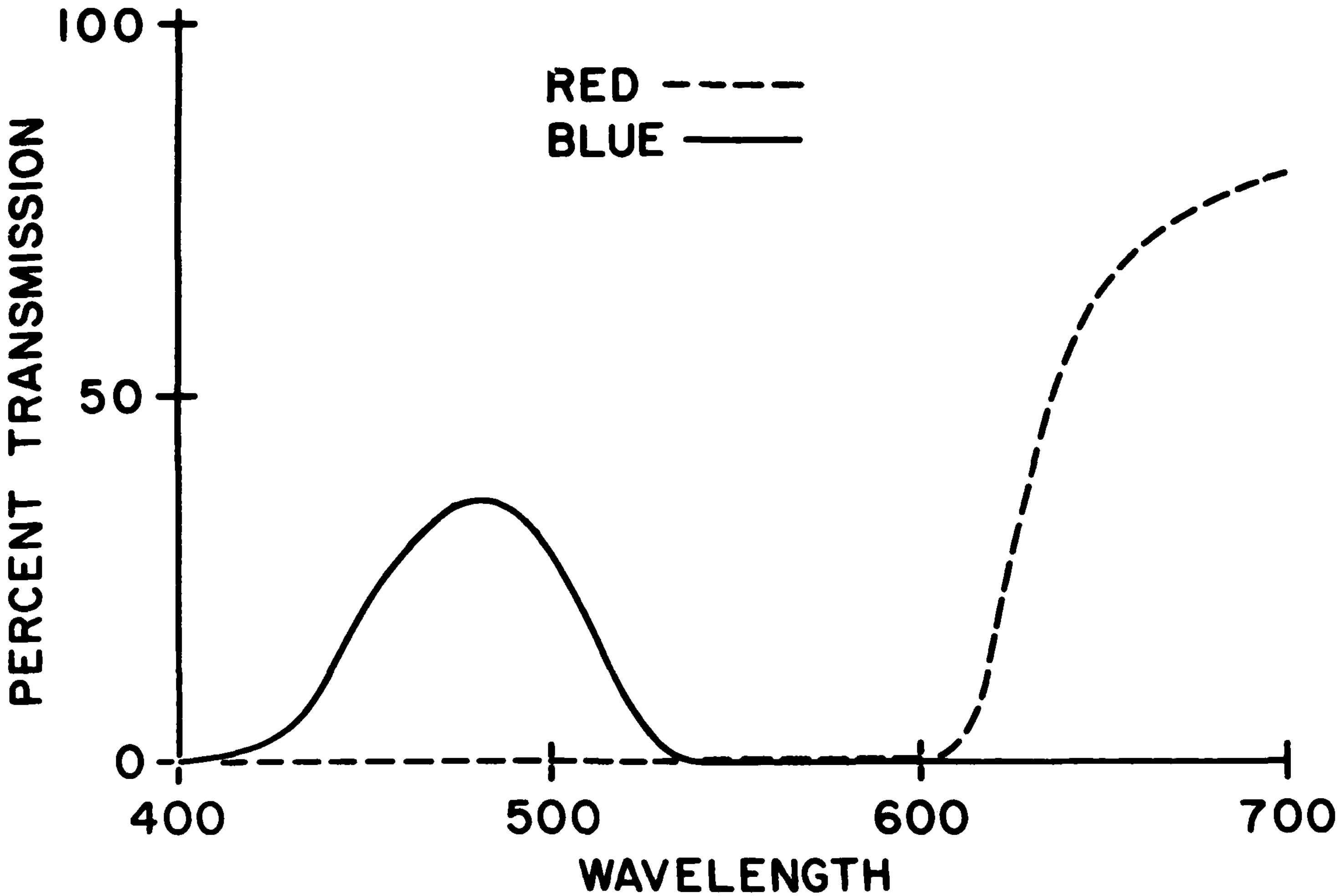

Fig. 1. Spectral transmittance of the red and blue filters

nation.

Two problems were done in a session by the same operator, one in red illumination and one in blue. Ten such sessions were completed; of these six were done by individual members of the sonar crew from one submarine undergoing refresher training and four by instructors at the trainer. The first problem was done in red illumination in half the sessions and in blue in the other half. In addition, the original bearing of the contact was equated for red and blue illumination.

<u>Results</u>

The detection ranges at which the operator correctly called a contact were recorded in kiloyards and then converted to ratios of ranges determined in blue/red lighting for the same man on the same day. These means and standard deviations are given in Table V, both for red and blue illumination and for order of presentation. Analysis of variance of the detection ranges showed no significant differences due to either color or order of presentation.

DISCUSSION

The results of these studies show that a large proportion of sonar technicians in the fleet prefer blue lighting and give some partial answers as to the reasons for this preference.

Of the four possible reasons stated earlier for the popularity of blue illumination, the most important would be a true enhancement of contrast sensitivity. If one could detect the same contact at a lower signal-to-noise ratio in blue light than in red, the tactical advantage would be obvious. Unfortunately, there was no evidence for this in the detection ranges measured in the 21B64A/AN/BQQ-5A trainer. It is of course possible to argue that we did not have the optimum set of conditions or problems for which enhancement might occur. However, we did set the level of illumination within the range used in the fleet and we did instruct the sonar technicians to operate the AN/BQQ-5A as they normally would. If under these conditions no improvement can be found, it is of limited generality.

Moreover, these results are in agreement with a laboratory study[10] just completed in which contrast sensitivity was measured under red, white, and blue illumination of two intensity levels and also with no ambient illumination. This study, employing an extremely sensitive measure of contrast sensitivity at different spatial frequencies, revealed no differences as a function of the color of the illumination. It thus seems safe to conclude that a true enhancement of vision is not the reason behind the popularity of blue illumination in sonar control rooms.

The statement that the color of the ambient illumination does not affect contrast sensitivity applies of course only to the low levels of illumination used in sonar control rooms and in these studies. Obviously it is possible to wash out the contrast on a CRT or a TV screen if the ambient illumination is bright enough and placed in a position such that it provides a glare on the surface. Glare is in fact sometimes seen on the displays in sonar, due to ill-advised placement of light

Table V. Detection ranges determined in the 21B64A/AN/BQQ-5A trainer.

Color	Mean	Standard deviation
Blue	61.3	4.31
Red	60.8	5.01
Ratio B/R	1.008	0.093
Order of Presentation		
First	60.1	4.03
Second	62.0	5.06

fixtures. However, in these studies, the quantity of light and the placement of the fixtures were the same for the different colors. Thus, there should be no difference in glare among the red, white, or blue conditions; this was attested to by the men's complaints of glare under all three colors.

A psychological effect was mentioned as one possible reason for the popularity of blue. Indeed, psychology might explain the large differences among the three submarines; for example, a popular and knowledgeable operator might voice a preference for a specific color and be able to influence the other members of the crew. However, the particular psychological effect mentioned was an improvement in morale resulting from the individual's perception that the change was done for his benefit. The prediction from this effect is that once the men had become used to blue, a change back to red would be viewed as an improvement. The implication of this is, of course, that there is no valid reason for the preference of blue over red.

There are, however, at least two other legitimate reasons. It is a fact of physiological optics that long wavelengths are focused farther away than short. The possibility that the increased accommodation required to focus red light on the retina might cause discomfort for some individuals is being investigated in another study.

Another fact of visual physiology is that the spectral sensitivity of the human eye shifts toward the shorter wavelengths at low or night levels of illumination. This makes low levels of blue light brighter and of red light dimmer than the physically measured quantities suggest; the greater ease of seeing the general outlines of the room could account for the popularity of blue. This, too, is being investigated further. It may well be that several of the possible reasons are involved.

Finally, it should be pointed out that white light shares with blue most of the advantages over red light and is preferable to blue in at least two ways: it does not interfere with dark adaptation as much as blue light does and it permits the use of color coding. White light, as employed in the SOT was not popular, however. The most common complaint was that it was gloomy and put one to sleep; this may have stemmed from the use of the black cloth filters hanging down from the fixtures; trials using another means of reducing the white illumination should be made.

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REFERENCES

1. CO, NSMRL ltr NSMRL-01, 3900 Ser 1-64, 18 Nov 1970.

2. NAVSEA 0964-000-2000. Lighting on Naval Ships. Chapter 12. Commander, Naval Sea Systems Command. 15 July 1974.

3. Mitchell, R. T., L. L. Franklin and B. F. Green. Charactron legibility with a broad band blue lighting system. Mass. Inst. Technology, Lincoln Lab. Group Report 38-18, 13 Oct 1955.

4. Green, B. F., R. T. Mitchell and L. Liaudansky. Charactron legibility with a red and blue lighting system. Mass. Inst. Tech., Lincoln Laboratory Group Report 38-22, 29 Feb 1956.

5. Commander, Submarine Development Squadron TWELVE spdltr FG5/12:kmr 9330 Ser 31/568, 31 Jul 1980.

6. Kinney, J. A. S., S. M. Luria, D. F. Neri, S. W. Kindness and C. L. Schlichting. Surveys of lighting and working conditions in submarine sonar shacks. NSMRL Rep. No. 955, Jun 1981.

7. Brown, J. M., F. K. Berrien and D. L. Russell. Chapter 10 in <u>Applied Psychology</u>, New York: Macmillan Co. 1966, pp 341-378.

8. Johnson, L. C. and P. Naitoh. The operational consequences of sleep deprivation and sleep deficit. AGARD-AG-193, Jun 1974, Technical Editing and Reproduction Ltd., London 1974.

9. French, R. S. <u>Passive sonar detection display studies: FY71-72</u> Naval Undersea Center, San Diego, CA, NUC TN 808 Jun 1972. (AD 906933).

10. Neri, D. F. and J. A. S. Kinney. Contrast sensitivity measured in low levels of red, white, and blue ambient illumination. NSMRL Rep. No. 989, Aug 1982.

Appendix. The Mood Scale and scoring instructions

Instructions: For each item, choose one of the four answers that best describes how you feel now. Then put an "X" in that box.

Item	Not at all	A little	Quite a bit	Ex-tremely	Item	Not at all	A little	Quite a bit	Ex-tremely
Active					Good-natured				
Alert					Grouchy				
Annoyed					Happy				
Carefree					Jittery				
Cheerful					Kind				
Able to concentrate					Lively				
Considerate					Pleasant				
Defiant					Relaxed				
Dependable					Satisfied				
Drowsy					Sleepy				
Dull					Sluggish				
Efficient					Tense				
Friendly					Able to think clearly				
Full of pep					Tired				
SCORES:	N		P		Able to work hard				

Scoring Instructions: Each of the four possible response categories is assigned a weight: "not at all", 0; "a little," 1; "quite a bit", 2; "extremely," 3. The sum of 19 positive items (active, alert, carefree, cheerful, able to concentrate, considerate, dependable, efficient, friendly, full of pep, good-natured, happy, kind, lively, pleasant, relaxed, satisfied, able to think clearly, able to work hard) is the P score. The positive items reflect feelings and behavior that generally decrease following sleep loss, i.e., feel less active, alert, efficient, etc. P scores range from 0 (extremely sleepy) to 57 (extremely active and alert). The sum of the responses to the 10 negative items (annoyed, defiant, drowsy, dull, grouchy, jittery, sleepy, sluggish, tense, tired) is tabulated in the same way to obtain the N score. The negative items usually increase following sleep loss. Negative scores range from 0 (extremely active and alert) to 30 (extremely sleepy). The two scales were included because it was found that certain subjects, such as those in the military, were more willing to admit positive feelings than negative, while the reverse was true of others.

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